

The Role of Simulation in Test and Evaluation

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Simulation has an essential role in test and evaluation. It provides efficiencies in U.S. Army acquisition strategies of mission-based test and evaluation and integrated testing and training, as evident with the Boeing Engineering Development Simulator during the Apache Block III force development test and experimentation testing. Simulators provide a representative environment where testers can safely test a product's or system's mission effectiveness. Ideal for integrated testing, simulators combine developmental and operational testing as they enable safe simultaneous testing of multiple elements. Additional benefits of cost and risk reduction were realized as well as aviation doctrine development.

Key words: Acquisition strategies; aviation combined arms tactical trainer (AVCATT); Boeing Engineering Development Simulator; hardware development; realistic environment; risk reduction; safety; software code development; test and training.

As a new U.S. Army aviator, I immediately learned the importance of simulators in both initial and proficiency flight training. Their significance became readily apparent recently when, as an acquisitions test and evaluation officer, I conducted two simulation-centric tests. The first test focused on the fidelity of the aviation combined arms tactical trainer (AVCATT) training simulator, and the second dealt with the utilization of the simulator to validate tactical employment methods of new functionalities of the AH-64D Apache Block III (AB3). This article identifies the test and evaluation (T&E) and training benefits of simulators using the Boeing Engineering Development Simulator (EDS) as a case study.

The AVCATT customer test's purpose was to measure the fidelity of a software lot upgrade. The test focused on the system's ability to replicate the Army's current fleet. AVCATT is a high-fidelity, full-mission simulator with reconfigurable cockpits that represent any of the five Army attack, reconnaissance, and utility helicopters; specifically, for this test it represents the AH-64D Apache Longbow and OH-58D Kiowa. For the user, the AVCATT is an air mission commander's tool to exercise command and control operations to conduct company/troop-level battle drills. Developers utilize customer tests to assess a product- or system-readiness state and its effectiveness by placing it in the hands of the user (soldiers).

Simulation's role in T&E was most significant in the AB3 Force Development Test and Experimentation

(FDT&E) in October 2009 at the Boeing facility, Mesa, Arizona, utilizing the EDS. The AB3 is the upgraded version of the currently fielded AH-64D Apache Longbow. The primary purpose was to validate aircrew and teaming, reconnaissance and attack techniques, tactics and procedures (TTPs) that incorporate the Unmanned Aircraft System (UAS) level of interoperability (LOI) II–IV, instrument flight rule, and other functionalities. The objective was achieved along with a windfall of other benefits to AB3 program, reconnaissance/attack aviation, and Army aviation doctrine. The most pertinent was refinement of the TTPs in manned-unmanned teaming operations.

UAS levels of interoperability (Dunbar 2010)

- LOI I: indirect receipt of secondary imagery or data,
- LOI II: receipt of imagery or data directly from the UAS,
- LOI III: LOI II plus control of the UAS sensor,
- LOI IV: LOI III plus navigational control of the UAS.

Mission-based test and evaluation (MBT&E): Focusing the data collection effort on mission effectiveness

For the unfamiliar, MBT&E is the Department of the Army/Office of Secretary of Defense standard for testing to ensure a system of systems or family of

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Figure 1. EDS cockpit (photo by Mike Goettlings).

systems meets the user's needs (mission task capabilities) as opposed to just "checking the blocks" on a requirement list. When done correctly, the end result is an increase in the warfighter's ability to accomplish his/her mission. The testers and evaluators must ask themselves, "Is the desired effect achieved"? To answer this question the test article must be examined in a representative operational environment; this is where the EDS enters into the equation. The consensus of the test team and test players supported that the EDS not only met but exceeded test expectations.

The EDS is a high-fidelity dome simulator with two independent but networked cockpits. From the pilot's perspective, the cockpits are to-scale functional duplicates of the actual article. They look, feel, sound, and interact with the crew member just as the aircraft does to provide representative human-machine interface data. Limited-motion cueing and vibration are produced under the crew member seats. Typical aircraft noise is provided from the appropriate direction and intensity level by a surround sound audio system. Recording capability of the crew station multipurpose displays is available as well as from over-the-shoulder cameras. Visually, the cockpit is encompassed by large, high-resolution screens that represent the Apache tandem cockpit field of view. Inclement weather or environmental cues such as shadow, sun, and moon position are present. Additionally, battlefield effects such as smoke, explosion, and fire are used to enhance realism. The EDS is supported by an auditorium that can display the crew member's multipurpose displays and a tactical map (*Figures 1 and 2*).

The instrument of execution, the EDS was more than capable of providing the virtual mission vignettes that replicate past, present, and potential threat scenarios as identified in the operational mission statement/mission profile document. Vignette development incorporated input from various Department of Defense agencies to ensure all known and forecasted



Figure 2. Auditorium (from Ferguson 2009).

variables were addressed. First, the mission vignettes were crafted to test AB3's enhanced capabilities in the traditional fight. The traditional fight is defined as a contiguous force-on-force scenario against a developed nation's army. The second objective was to determine the effectiveness of the aircraft capabilities in today's contemporary operating environment. The contemporary operating environment was representative of the insurgent fight in Afghanistan and Iraq theaters of operations. A hybrid fight was incorporated in between for a transitional phase, characterized as a simultaneous fight against both a defeated standing force and a constituting insurgent force.

The most apparent advantage of the simulator is that it provides a substantial amount of data compared to an aircraft-based event and a realistic combat theater battle rhythm. A mission set was assigned to each of three aircrews throughout an eight-day record test. A total of 23 operational missions were conducted, with the 24th mission reserved as a test/verification (prove-out) mission to resolve any tactical steering committee changes. Mission preparation, including operation orders, intelligence briefs, rules of engagement, air mission briefs, rehearsals, and mission debriefs, were conducted in accordance with a daily combat battle rhythm. A total of 75.6 simulator flight hours were flown during the 24 missions. Compared to using actual aircraft, the EDS obviously facilitated a more robust schedule (*Figure 3*). The EDS overlapping mission cycles were more representative than a typical single-mission-per-day aircraft event. The operational tempo generated an optimum data collecting effort

H-HOUR SEQUENCE													
		FDT&E SIMULATOR AVAILABILITY TIME											
7:00 AM		8:00 AM		9:00 AM		10:00 AM		11:00 AM		12:00 PM			
1st Crew	H - 2.0 OPORD / Test team brief / Mission Planning	H - 1.0 S2 / S3 Brief	H - 0.5 Crew / TTP Brief	Start Mission Vig1 Day (Crew 1)		H + 1.5 AAR / Tactical Steering Cell	Cafeteria hours						
Who	USG	Developer	USG	USG / Developer		USG							
Location	Briefing room	Auditorium	Briefing room	Auditorium / Control room / EDS		Conference room							
Aircrew 1		Pilot 1 Co-pilot gunner 1		2nd Crew	H - 2.0 OPORD / Test team brief / Mission Planning	H - 1.0 S2 / S3 Brief	H - 0.5 Crew / TTP Brief	Start Mission Vig1 Day (Crew 2)		H + 1.5 AAR / Tactical Steering Cell			
		Pilot 2 Co-pilot gunner 2			Who	USG	Developer	USG / Developer		USG			
		Pilot 3 Co-pilot gunner 3			Location	Briefing room	Auditorium	Auditorium / Control room / EDS		Conference room			
Aircrew 2				3rd Crew	H - 2.0 OPORD / Test team brief / Mission Planning	H - 1.0 S2 / S3 Brief	H - 0.5 Crew / TTP Brief	Start Mission Vig1 Day (Crew 3)		H + 1.5 AAR / Tactical Steering Cell			
					Who	USG	Developer	USG / Developer		USG			
					Location	Briefing room	Auditorium	Auditorium / Control room / EDS		Conference room			
Sim Prep for Next Day													

Figure 3. FDT&E daily schedule.

while maximizing resources in a significantly safer environment.

FDT&E and limited user test (LUT) comparison

- Test team personnel: 15 versus 103,
- FDT&E test cost: 5 percent of LUT cost,
- risk assessment level: low versus high,
- record test days: eight versus nine,
- record data collection events (missions): 24 versus nine.

High fidelity was achieved by seamless integration of individual player entities into a multifacet battlefield by the operations officer from the simulator control room. The key to a dynamic battle simulation was having the right personnel (role players) in the room (see control room personnel list below). Through the operations officer, control room personnel had vetted interactions with the battle simulation and aircrew. To establish tactical realism, the operations officer was centrally located during the vignettes to orchestrate the event while reducing game-ism as much as possible. After sequencing of role player actions, filtering simulation distractions and nuances from the aircrew was the operations officer's next most important task. Conversely, other distractions such as sketchy radio communications and incorrect intelligence information were incorporated for imperfect conditions—fog and friction of war. A threat analyst ensured simulated enemy tactics and systems were employed in accordance with their doctrine and recent Afghanistan and Iraq battlefield reports. Ranges for probability of hit

and kill were in line with demonstrated enemy capability. A training and doctrine capabilities manager recon/attack subject matter expert served as an honest broker to adjudicate weapon engagements. Video record capability of the EDS was instrumental in mission after-action review, continuous TTP refinement, and test team after-action review to ensure the test team was synchronized.

EDS control room personnel

- Operations officer;
- test officer;
- subject matter expert;
- UAS ground control station operators;
- friendly element controller:
 - infantry, armor, artillery, and joint services;
- AH-64D Apache wingman (laptop networked);
- aviation tactical operation control;
- Enemy force commander:
 - infantry, armor, artillery, and insurgents;
- Threat analyst;
- EDS operator;
- EDS support personnel:
 - simulator operations, environment conditions, and noncombatants.

Integrated testing: Fusing developmental and operational testing in one event

Integrating developmental and operational testing captures test efficiencies by making use of all data available throughout testing as opposed to two distinct test phases. Integrated testing is commonly achieved by increasing operational realism in developmental test-



Figure 4. Unmanned Little Bird (photo by Mike Goettings).

ing, therefore, improving the likelihood of success in subsequent operational tests and ultimately in combat. Direct user feedback early in developmental testing greatly reduces the cost of modification. Simulators are ideal vehicles for integrated testing, as they enable parallel testing of multiple elements without adding risk. Simultaneous testing of a developing system and its application not only reduces resource consumption but also optimizes its employment once fielded. This was an operational event with a substantial amount of developmental testing incorporated.

The ability to temporarily bypass an immature key component during developmental testing is a time and cost benefit that simulation provides to complex programs. In the AB3 program, the EDS allowed the testing of capability that has yet to reach fruition. With the Extended Range/Multi-Purpose UAS still in development, it was advantageous to conduct the FDT&E in virtual simulation. The LUT utilized an experimental aircraft, a modified Boeing AH-6 known as the Unmanned Little Bird (*Figure 4*). The EDS allowed the program to proceed on schedule while a surrogate for the UAS, which was required for the LUT, was under development.

Operationally, the effects of the AB3 functions on workload and situational awareness were analyzed in addition to airspace management and engagement geometry. Multiple functions of air weapon system employment were examined simultaneously in the safety of a virtual environment. The currently fielded Apache is a complex weapon system with a high workload. Introduction of the additional task of controlling a UAS in teaming operations was a critical concern of the aviation community. The EDS provided a means of direct comparison of legacy Apache to AB3 crew member workload, situational awareness, and mission effectiveness. The Army Research Laboratory-Human Research & Engineering Directorate repre-

sentative was able to isolate when or if a crew member became task saturated or lost situational awareness. The tactical steering committee used these observations to change intracockpit delegation, task division, and realignment of crew duties.

The greatest risk to dissimilar aircraft operating in teaming is other aircraft. Therefore, AB3s airspace management was a critical element of TTP development, reducing the risk of placing mixed aircraft teams in close proximity of each other. At this point, the TTPs moved from concept to a tangible employment method. Tactically in cooperative engagements, the geometry of the (designating) UAS in relation to the (firing) AB3 was honed to definitive envelope to be field tested. Equally important, the most efficient (quickest) method to achieve the correct geometry was refined. Appropriate engagement geometry requires both aircraft to have the correct combination of several factors, such as slant range; engagement fan (azimuth); air speed; timing; and loitering patterns to acquire, designate, and process targets.

The AB3 FDT&E leveraged developmental testing of both software and hardware. The EDS serves as a continuous test bed for the software code development, since it uses exact production representative components and processors (black boxes) as the AB3. Engineers routinely use the EDS as a code prove-out vehicle to answer "what-ifs" and bring anomalies and glitches to light. In hardware development, the pilots were fitted with modified HGU-56/P as opposed to the currently fielded Integrated Helmet and Display Sight System. The modified HGU-56/P helmet offers the same mounted monocular helmet display unit with flight and targeting symbology overlays. A new helmet system, range of motion, sensor location, cord restrictions, field of view, and fitting are critical issues of pilot-vehicle interaction that were examined in depth. Other than the aircraft, the EDS is the only environment where the pilots perform normal operational head movements. Two pilots stated the HGU-56/P helmets compared to the current Integrated Helmet and Display Sight System helmet as the best fit in 20 years of aviation flying service.

Training: Test benefits and more

Beyond the FDT&E test, the EDS contribution to the Apache Block III limited-user test was invaluable. LUT pilots underwent a two-week training phase consisting of academics, EDS sessions, and training flights in the developmental AB3 aircraft. The LUT crews reinforced their academics with 60 cumulative flight hours of EDS practical (operational) application, all of whom stated that using the EDS as a training aid was advantageous. Both FDT&E and LUT test team

and players recommended the use of the EDS as a training aid in future testing as well as unit fielding. Mission segments from the FDT&E missions were recorded and incorporated into the LUT refresher training. At the conclusion of the FDT&E, a training program was finalized for LUT and first-unit-equipped pilots. Also, training of the test players identified gaps to be incorporated into the Apache Longbow Crew Trainer and the new equipment training package. Training was not limited to the test players; the LUT test officer, analyst, data collectors, and data authentication group monitored training and missions to learn firsthand the AB3's capabilities. FDT&E video was used for orientation and training material, which was especially beneficial for video data reducers who were not familiar with recon/attack operations.

Simulator benefits

- Minimal risk to crew members,
- a "low" overall test risk assessment,
- significantly lower test cost,
- larger data collection availability,
- reduced test team, player, and equipment requirement,
- less restrictive:
 - existing human use committee approval,
 - aircraft airworthiness certification not required.

Conclusion

As evident in the AB3, simulation's role in test and evaluation is that of a key facilitator in the acquisition strategies of MBT&E and integrated testing. Though simulation cannot (and should not) be used exclusively as a testing application, it offers significant reductions to risk and cost and increased innovative benefits when supplementing field testing, especially when the system is not mature. The EDS met and exceeded the test objective of TTP refinement by providing several other MUM products and valuable training material. Critical pilot workload and situation awareness differentials were identified that were essential in developing efficient and safe employment of the AB3. Most notably, the EDS eased the paradigm shift of reconnaissance and attack aviation operations from autonomous weapons team to MUM teaming.

Test products

- Level 3 database
- Abbreviated operational test report

- Revised TTP manual
- MUM platform (handshake) checklist
- Operational test agency milestone C assessment report input
- Recorded mission vignettes (LUT training refresher)

Residual benefits

- MUM airspace management and engagement geometry
- Vetted AB3 training program
- Identification of tactical suitability and practicality of LOIs
- Standardization of MUM terminology



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Figure 5. FDT&E test team (photo by Mike Goettings).

Acknowledgments

AB3 FDT&E test team (*Figure 5*): MAJ Cornelius L. Allen, Jr. (test officer), Dr. Bruce Wardlow (analyst), LTC Brian Apgar (assistant test officer),

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